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"Pulse": Bridging the Gap Between the Tangible and the Intangible Through the Medium of 3D Printed Stop-Motion Animation"

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by
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Abstract

This thesis creates a short-form art piece primarily using modular 3D printed forms, photographed in a stop-motion animation style, and composited digitally into a finished product. It creates the lab space needed to print and photograph the piece; including lighting, set, and photography equipment. This project shows that it is possible for a single artist to come up with sufficient time-saving techniques in order to complete an entire work from start to finish. This work also shows it is possible to create a work that will inspire the emotions of fear, horror, and frustration that comes with the birth of the new.

Artistic Statement

I do not want to create narratives, I want to inspire them. I want to give the consumer of my art an experience they can build off on their own. I give them a push, then leave them to their own devices. Where they take my art is up to them, their own experiences, their own prejudices. I want to upset, I want to unsettle.

We create creatures. We create humans. We create beings. Do we dare to let those beings out into the physical world? Think of all the horrors we could bring to life. What if we set them free upon the unwitting world?

Over the past years I have concentrated my artistic energies on the digital world, but before that my work remained almost solely in the physical realm. What if I could combine these two modes; take a piece of digital ephemera and translate it into physical reality? Is there a place for the physical arts in the digital production world?

3D printing is nothing new. Even 3D printed stop-motion animation is being accomplished by some of the biggest animation houses in the world. However, those are narrative pieces. I create sculpture with no inherent narrative. I am taking this new medium of translation and am bending it to my will to create my own new works that are both animation and sculpture, but also not solely animation or sculpture: a new hybrid digital media form.

Dedication

This project is dedicated to: my long-suffering husband Eric, my parents John and Lois, and my cohort at the Zucker Graduate Education Center.

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Introduction And Motivation

1.1 Fomentation of Ideas

1.1.1 The Tangible Versus the Intangible

I have found that, quite often, students will reach for humor and comedy when creating a project short. There is good reason: comedy is easy to fit into a short format feature. A setup and punchline can easily be achieved in the span of a few seconds. Personally, I have never been good at comedy. While it can be learned, humor and timing can be elusive, depending on a person's world view and upbringing. I tend to the more serious and grave, and my jokes often fall flat. That leaves me with a quandry: what to create a short piece around? Drama, mystery, suspense — all typically require a certain amount of narrative. While there is nothing wrong with a narrative work, that is not my ultimate goal. I prefer to evoke a singular emotion. The easiest emotions to conjure are our basest — desire and fear. I chose the latter. Horror. Dread.

To create an entire creature would be very limiting. Whether a creature evokes a feeling of dread in a person is quite subjective. What is horrifying to me may not be to another. So that shelves the fear of the seen. But what about the unseen? The unknown? That is a fear that more will share. Finding a person who does not fear the unseen creature lurking in the dark would be difficult. Perhaps that is too unknown for a project like this. If we see nothing this would become a different kind of sensory project, a project for another day perhaps.

I need to have something in front of the viewer, but something the viewer cannot see.

Something that may well contain an untold horror, but one that exists only in the mind of the viewer. An ordinary egg.

Once I had finally decided on the concept of an egg, I was lost on where to place the it. Should it be out in the open? Resting on a floor? Clearly and brightly lit? Tucked into a corner? Cuddled in a nest? Lurking in a shadow? None of these felt right. I needed to find a reason for the egg to exist in a place we could observe it. I thought of a museum exhibit, but that felt too sterile, but I was drawn to the idea of the egg as a specimen. The trope of the mad scientist's lab full of strange organic objects preserved in formaldehyde or other strange chemicals came to mind. A scientist's lab is a place where a person could sit and watch a strange object without it being considered an unusual activity. One could stare into a specimen jar and observe its bizarre contents, but what if those contents proved to still be alive and moving? An unsettling thought, and one I enjoyed.

The idea of the morally suspect experiment as horror subject has existed in literature for centuries. It is famously portrayed in Mary Shelley's *Frankenstein*, where the doctor concentrates more on the content of his work than on the potential repercussions of scientific experiment, but even he is frightened and awed by the prospect of his creation. "I saw the hideous phantasm of a man stretched out, and then, on the working of some powerful engine, show signs of life and stir with an uneasy, half-vital motion." [17]

Frankenstein is only one example of the horror of the scientific oddity. Authors such as Lovecraft, Le Fanu, Polidori, Stevenson, and Wells have all delved into the realm of creation run amok. I wanted to create a project that could have easily fit into a visual retelling of one of their stories, an object that perhaps contains some sort of life.

This led me to the title "Pulse." I wanted a simple title that did not convey too many expectations to the viewer. Since the general topic of the piece was life I thought about how humans check for signs of life on a creature. One of the first things is to check for a pulse. I'm creating a tangible object, perhaps it has a pulse, perhaps it is alive.

In the field of Digital Production we exist to create primarily intangible ephemera. Our works are viewed, enjoyed, then disappear into the void of "uncreation." We bring things to life: characters, stories, worlds, emotions; only to have them vanish into memory. Few and far between are the physical remnants of these creations; a printed poster, a lobby card, scribblings on a white-board. With the rise of 3D printing we've begun to see a glimpse of how the digital can invade

the tangible world. A spinning creation on a monitor can, with a little work, become a spinning model in the hand. No more need to reinterpret a digital creation by hand. We can print, we can injection mold, we can take out the laborious process of recreation and bring our idea straight from the computer into the real world.

Studios such as LAIKA are investing their entire fortunes into this production model. Originally only their method of rapid prototyping, 3D printing has morphed into a full-on production level process. [18]

1.1.2 "Wooly-Headed" Art in a Technical Context

Years ago I created a project for an introductory computing class. It was an interactive visualization of a dream created in HyperCard (yes, it was long ago). My professor looked at it in silence for a while, then he looked at me and said "What are you, some sort of wooly-headed artist?" I think he meant it in an unflattering way, perhaps my head was full of wool, but I embraced that term. I'm a wooly-headed artist. Just because I enjoy creating with digital media doesn't make me any less an artist. It doesn't make any of less of an artist. The most technically-minded among us still creates. Its becoming cliche to say so, but there is beauty in code and numbers. There is beauty in getting a metric just right; in adjusting a value until an output in perfect. This is artful. This is art.

Just because I wanted to create something tangible for my thesis does not mean I wanted to totally ignore the digital side. There is precision in 3D printing. There are numbers and values that must be adhered to in order to create a desired outcome: just the right temperature of a print head, just the right proportions of an object so it slides together. just the right camera settings to create the perfect shot. These are all as important as the artistic idea behind the piece.

Yes, I'm technically minded. Yes, I love numbers and precision; but at heart I am still that wooly-headed artist who enjoys creating the weird and unexpected. I still create, even if I dont get my hands dirty. Its all still art, and perfectly valid, despite what my old professor might think.

1.2 Artistic Influences

I first viewed the short Miazmat, shown in Figure 1.1, a surreal 3D-animated short inspired by the works of artist S.I. Witkiewicz, at Siggraph 2018 in Vancouver, BC. [10] While the animation

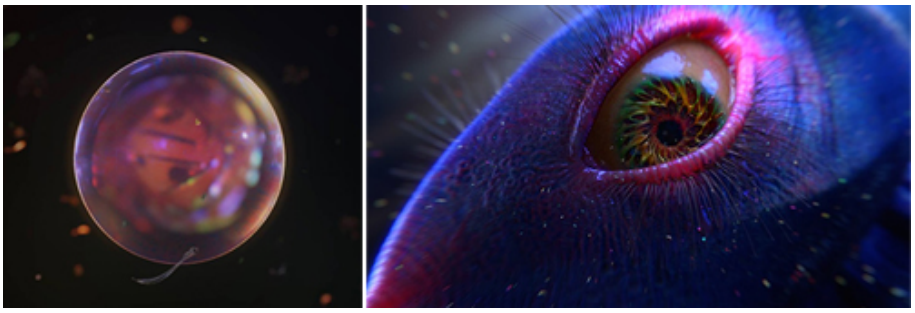


Figure 1.1: Platige Image. "Miazmat." Online video clip. YouTube. YouTube, 28 Sept. 2018. 28 Sept. 2018.

and the effects were certainly spectacular, it was the imagery that caught my eye — all of these surrealistic biological forms suspended in a void churning and sputtering. An egg begets life that, in turn, begets a multitude of creatures. The idea that a single cell could become almost anything, from a daydream to a nightmare. It is a beautiful, and somewhat foreboding, thought.

The team at Platige Image grasped onto Polish artist S.I. Witkiewicz's idea of the "pure form" as portrayed in a painting of his known only as *Composition*, shown in Figure 1.2. The theory of the pure form is a philosophy espoused by several in the abstract movement of the early 20th century, based very loosely upon the Platonic theory of Form — it is not the form itself, but the effect the form has upon the consumer — that is the art. The artist may create a piece physically, but it is not until it is fully taken in by the viewer or listener that the piece becomes art. [22] Storytelling and narrative are either secondary, or not necessary at all, for a piece of art (whether a physical painting, a play, or a musical piece) to become real. There is no need for understanding and comprehension; the experience of the art is what is important. As Witkiewicz puts it: "Art is the expression of what I call faute de mieux metaphysical feeling, or in other words (please, pay close attention) the expression of the directly given unity of our individuality in formal constructions of any elements (complex or simple), in such a way that these constructions affect us directly, and not through cognitive understanding." [21]

Salvador Dalí's 1943 painting *Geopoliticus*, shown in Figure 1.3, is commonly cited by students studying surrealist art. [5] With good reason! It is an amazing painting by one of the quintessential surrealist painters. For that reason I was a bit hesitant to include it, but I cannot deny that the form of the human hatching from the egg is very appealing. Dalí captured the stretch and distention of the surface of the egg perfectly: the terrifying feeling of a human trapped inside

Figure 1.2: *Kompozycja (Composition)*. Stanisław Ignacy Witkiewicz. 1922. Oil on canvas. National Museum Kraków, Kraków Poland.

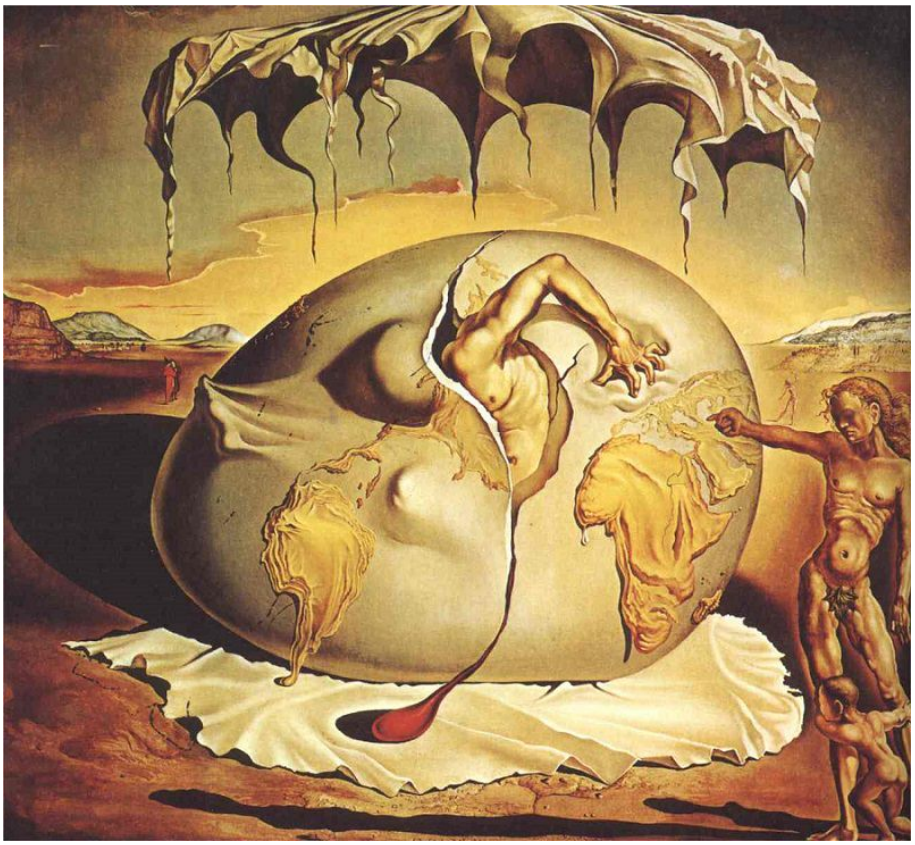


Figure 1.3: *Geopoliticus Child Watching the Birth of the New Man.* Salvador Dalí. 1943. Oil on canvas. Salvador Dalí Museum Inc., St. Petersburg, FL.

an egg. Will he hatch before he is suffocated? Is it truly a human, or is it a creature that merely resembles a human. Those are questions I sought to answer in my piece.

In Dalí's case he was referencing the dawn of a new world order. I am not looking as deeply into the political symbolism of this painting. I am looking more at his use of the egg form as a container for an unknown or a semi-unknown. We know the egg contains a man, but we do not yet know the nature of this man. The egg holds the unknown. It is not the first time an egg appears in a Dalí painting. *The Metamorphosis of Narcissus*, seen in Figure 1.4 is another Dalí work that includes the symbol of the egg holding the potential for great good or great evil.

Carrying on from Dalí's paintings, I find myself drawn to his foray into animation. In 1946 Dalí entered into an unlikely partnership with Walt Disney to create the seven-minute surrealist work *Destino*, a still from which is shown in Figure 1.5. Although neither of them lived to see the project to fruition, a dedicated crew brought the animation to life in 2003. [14] I consider this piece

Figure 1.4: *The Metamorphosis of Narcissus.* Salvador Dalí. 1937. Oil on canvas. Tate Modern, London.

Figure 1.5: *Destino.* Directed by Dominique Monfry. Written by Salvador Dalí, John Hench, and Donald Ernst. Walt Disney Pictures. 2 June 2003.

Figure 1.6: *Closer*. Directed by Mark Romanek. Written and produced by Trent Reznor. Performed by Nine Inch Nails. Le Pig, The Record Plant, A&M Studios. 30 May 1994.

to be one of the premiere masterworks of modern animation. Through a series of tableau it tells a fractured tale of beauty, loss, and persistence.

I have long admired the use of distorted and corrupted natural forms in the piece. I wanted to try to incorporate some of that sense of the strange and the other into my own piece. This is why I chose an organic distending egg. A common organic form, like those found in *Destino*, but containing the unexpected and disturbing: a humanoid form.

From there I looked for an already existing reference for the picture I had in my mind. The music video for the song "Closer" came to mind. The video is done in a sepia tone, with a degraded granular grain film, a sample of which is shown in Figure 1.6. The shots come quickly, as if one is

peeking in on something illicit. This appealed to me, it is the idea that I've created an object that can be viewed, but perhaps it shouldn't be. Perhaps it is too disturbing to behold, so only take a glimpse. The vignettes in the video are mostly violent and disturbing. While I don't have the resources to create something as disturbing, I hope to capture the general feeling of the video.

I have also taken cues from the visual style of the video. The sepia tone I have translated into a greener, but no less desaturated, tone. The dark vignetting of the frames to create a feeling of claustrophobia can bring my egg into a smaller visual space. Since I do not have a full physical set, I can use that vignetting to create the feeling of volume.

1.3 Stop-Motion Inspiration

Stop-motion animation has been around since the earliest days of film-making. From J. Stuart Blackton's lost feature *The Humpty Dumpty Circus*, to the famous Georges Méliès' fanciful works, early filmmakers used stop-motion to create images more fantastic than anything they could create in the real world. [8] While these early works were often simple — utilizing children's toys or cut paper for the models — they were no less ingenious. Theatrical cinema was still in its infancy, and animation was still a novelty. [20] Seeing an actual object move across the screen without apparent human aid must have fascinated some audience members. Techniques of stop-motion animation continued to improve decade after decade. Some filmmakers utilized clay to sculpt their multiple character forms, creating the art form of "claymation." [16] Others used simple or sophisticated armatures to control the model positioning. Studios such as LAIKA use highly-detailed interchangeable models on armatures to achieve their incredibly detailed animations, as seen in Figure 1.7. [19] While these modern features may bear little resemblance to the stop-motion features of the late 1800s, they still carry the same DNA. The process, although streamlined, is still the same. No matter how sophisticated the production, stop-motion is still stringing together photographs of models to create an animation.

"Pulse" continues the grand tradition of stop-motion. It creates an impossible object in the real world. No doubt that the egg could be replaced by a 3D animated model, but that would rid the piece of its tangibility. A practical effect might be possible to create, but would require significant effort for what might be a very unsatisfying payout. Instead I have taken the techniques of those early filmmakers, combined them with the modern advances of today's animation studios,

Figure 1.7: LAIKA Studio artists work with interchangeable parts on the model of Kubo for the animated feature *Kubo and the Two Strings*. Photo courtesy of Digital Trends.

and created my own work. Thus, I owe gratitude to those who came before.

The short film "Bone Mother" from studio See Creature Animation embraced its 3D-printed style. [2] As Figure 1.8 shows, the wrinkles in the face of the Baba Yaga character are represented by the printing layer artifacts. I greatly respect this use of the 3D print medium without the desire to disguise it as something else, keeping the evidence of the print front and center in the production. While I did briefly consider polishing or painting my models to disguise any evidence of the printing process, I discovered that this would be very time consuming and would hide the relics of my production process. While there is nothing wrong with using 3D printing to create polished models that resemble hand-sculpted or machined creations, I want to show the work that went into my piece. By leaving behind the artifacts of printing I can create a unique texture to the model while proving the creation story of the work.

When I was first conceptualizing this project, I had envisioned something similar to design agency DBLG's "Bears on Stairs" project — a series of solid models (see Figure 1.9), one per frame, photographed and then shown in order. This does provide a smooth animation and makes the photography process very simple: place a model, make the picture, replace the model with the next in the series, make another picture, repeat. This works well for a short animation like "Bears on

Figure 1.8: See Creature Animation. "Bone Mother." Online video clip. YouTube. YouTube, 25 Oct. 2018. 25 Oct. 2018.

Figure 1.9: Models from DBLG and Blue Zoo's project "Bears on Stairs." Each model is a separate frame of animation.

Stairs." At only 50 repeating frames there are not a lot of models to keep track of or much printing to do. I wanted Pulse to have at least 1400 frames. Printing 1400 separate models, while possible with a commercial printing laboratory, is not feasible for one person with a personal printer and limited time. [13] This is why I looked to studios such as LAIKA and their interchangeable models, as shown in Figure 1.7. [23] With interchangeable and repeating parts I could print 150 interlocking pieces and recombine them in different configurations to create new objects. In this way I would be able to cut my printing down by an order of magnitude, and increase the time I could spend on research and finishing.

Chapter 2

The Pre-Production Process

2.1 Researching Lighting and Photography

In researching the lighting for Pulse I found it easiest to break the work down into two separate categories: the artistic and the technical. The artistic allowed me to focus on the look and feel I am going for, creating color palettes and finding inspirational examples. The technical then allowed me to focus on sourcing the materials I needed to build the rig to complete the project.

2.1.1 Artistic

This piece is presented as if we are peeking in at a laboratory biological specimen. Not a well-lit modern laboratory, though. This is a more sinister "mad-scientist"-style laboratory. The feeling should be of a dimly-lit, unnerving, and uneasy space. Think of specimen jars (such as those in Figure 2.1), creatures preserved in formaldehyde (such as those in Figure 2.2) — experiments that are morally ambiguous. We are peering into a small and intimate space. Because of this the lighting must match a small space. [12]

The light is indirect and diffused, mostly coming from bounced light. The scene shouldn't be completely washed in a single light, though. That would make for a dull composition. To counteract this I have added a bit of under-lighting. This is achieved by placing a smaller light shining off a reflector underneath the object. On a human face under-lighting creates strange and uncanny shadows. Because the theme of this project is something almost supernatural and the goal

Figure 2.1: Hansen, Therese *Glass jar with a sea creature preserved in alcohol on a shelf.* Image used under license from Shutterstock.com

Figure 2.2: Lee, Ally *A mad scientist's collection of tubed fetuses and specimens evokes a horror film or disturbingly curious sentiment.* Image used under license from Shutterstock.com

Figure 2.3: Green colorway.

is to leave the viewer feeling uneasy, we need to add plenty of destabilizing elements and visual cues. This feeling can be created using the base content and unstable camera angles, but adding an element of uncanny lighting is an easy way to compound the strange.

On top of the style of lighting, I can also create some very unsettling effects using just the color of the light. Since I am creating an unsettling scene I had to choose an unsettling color palette. I have chosen a green to yellow organic color scheme, shown in Figure 2.3. Used in some context greens and yellows can be refreshing and welcoming, but green and yellow can also be sickly and disgusting. They're the colors of decay and bile and waste. When a specimen is preserved in formaldehyde it will eventually begin to take on a yellow tinge. My goal was to replicate this type of color using the light.

All of my lighting needs were achieved by using a traditional 3-point lighting setup with a small modification. I used the standard key and rim lights, but instead of a traditional fill light I placed the third light below and slightly in front of my subject. This layout is shown in Figure 2.4 That provides significant under-lighting. I have attached my subject to a metal rod that I can then magnetically attach to a steel plate stage. The length of this rod keeps the model high enough off the stage to have the light directly shine up at the model, but if it wasn't sufficiently far from the stage the light could be bounced off a reflector.

2.1.2 Technical

In order to hold the lights far enough away from the object, I created a framework of extruded aluminum, an example of which is shown in Figure 2.5. I added several cross bars to the box to provide ample attachment points, but the modular nature of the extruded aluminum means more cross bars and attachment points can be easily added as needed. The frame I created, shown in Figure 2.6, was approximately 6.0' x 3.0' x 3.0', but could be modified to be larger or smaller as needed.

The aluminum framework also gives us the option to attach other things to assist our set construction. Depending upon the practical lighting tests, it may be necessary to use scrim to further diffuse the light, or possibly obscure the entire scene. Multiple attachment points will allow the installation of scrim wherever necessary. Because I want this scene to appear to have a high level of atmospherics, I had to come up with a few ways to create them while ensuring consistency between frames. One way would be to create it all digitally and composite it all in at the end, but I

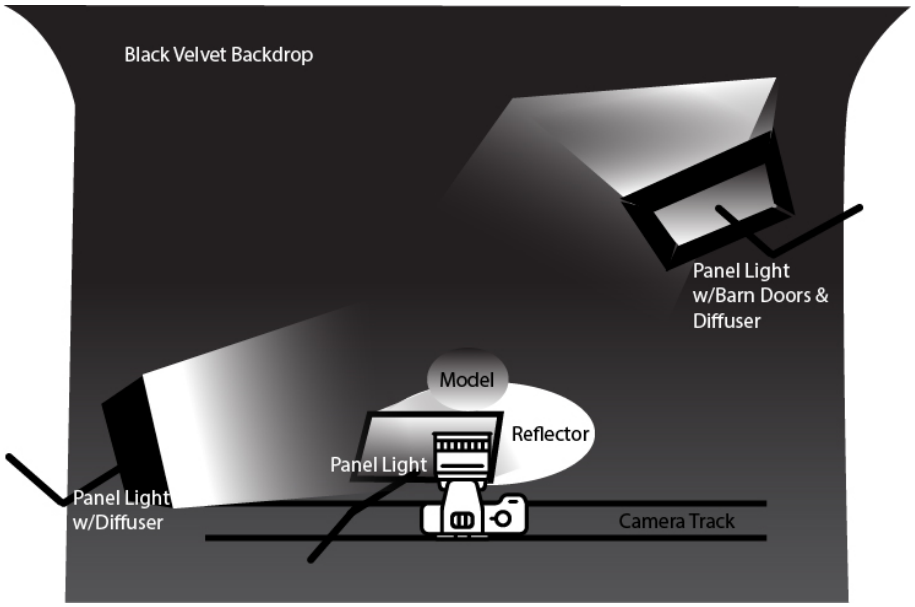


Figure 2.4: Lighting diagram.

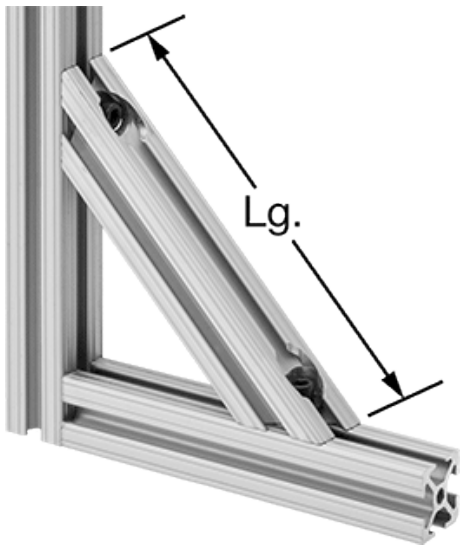


Figure 2.5: Extruded aluminum.

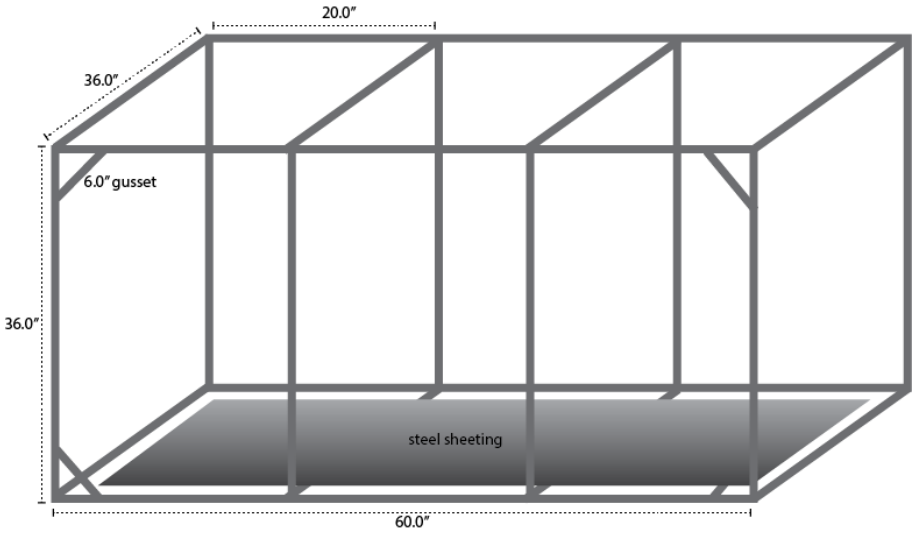


Figure 2.6: Lighting stage framework diagram.

was trying to avoid doing too much digital manipulation. Because photographing actual vapor would be far too inconsistent from shot to shot, a scrim would seem the ideal solution. After attempting several test shots with a scrim, I eventually came to the conclusion that atmospheric effects were best left to the post-processing digital compositing. Getting enough light on the model while having the shot through the scrim capture enough detail was just too difficult.

As for the lights themselves, I originally looked into using actual theater lanterns. Most larger studios that work in stop-motion use these theater lanterns. While traditional theater lighting does allow for maximum flexibility, it is not necessarily practical for lighting a small scene. Most theater lighting instruments are designed to light large areas, but we are working with a more intimate scene. We are also working in a much smaller physical space. The heat output of, say, a traditional Fresnel lantern can be fairly intense, even if it is just a few inches in diameter. This would make working in a tight space difficult and possibly hazardous. Because of this I turned to photography lighting setups. [4]

Finding a workable and affordable lighting setup proved to be challenging. Because of the small space I was able to narrow the lights down to LED lights. They output significantly less heat than tungsten or plasma lights. LEDs use standard 110 VAC supply, so there's no worrying about the electrical supply. LEDs also have the advantage of being significantly cheaper than other types of light. There do exist some very inexpensive light sets for amateur photographers, but research yields

multiple complaints of consistency not just between lights, but within individual lights themselves. During one photo shoot the light may have a certain temperature, but the next time the light is turned on that temperature may not be exactly the same. [9] Because stop-motion is a series of photos it is imperative that there be consistency of lighting between frames. For this reason I chose a mid-range LED panel lighting set.

The light set I chose also has a few extra abilities that proved useful. The first one is the feature that it has a variable temperature setting. Many lighting sets come pre-calibrated to a specific temperature; some to the 3200K neutral temperature, and some to a 5600K daylight temperature. Being able to adjust to a setting between these gives far more flexibility in creating subtle lighting changes. Another is the ability to use lighting gels to control color. The lights I choose have slots for at least 2 colored gels so the desired green and yellow tint can be achieved. Third is dimmability. A good mid-range light will have the ability to adjust brightness from 100% down to almost 0% without encountering much, if any, flickering. This is especially important when lighting a small space where 100% intensity of light would blow out any pictures. Last feature is a built in barn door system. Barn doors on lighting instruments allow control of the light spread. In this way light can be directed on to a specific part of our stage. The advantage of a barn door system over a focus-able beam is we don't have to worry about a tight beam of light creating a hot-spot on our object. Barn doors allow us to have a measured amount of light spread without having to worry about differing cone intensity.

2.2 Setting Up the Photography Lab

It is easy, in our DPA world of digital creations, to forget that we can use our hands to build in the real world. We're human flesh that can paint and sculpt and build. I wanted at least a portion of this project to include the construction of a physical lab that will facilitate not only my own project, but future similar projects. A stage on which to create new art. It begins with an empty room; an auxiliary, unused space. A blank canvas, so to speak. I designed and created a custom welded metal and wood table that can stand the weight of a person and can allow hands-on equipment manipulation. When one wants to get the perfect shot, getting into the right position should not get in the way. On top of this robust table I set up a framework of extruded aluminum. This cage is easily manipulated and resized to allow for light and other equipment mounting. A

system of sliding rails, combined with swiveling light mounts yields any angle needed to light a small scene. A steel plate creates a solid and almost un-moving stage. Magnetic mounts with threaded rods of differing lengths allow for objects to move across the stage in any direction — be it x, y, or z. Any kind of backdrop can be hung from the rear of the cage. This is perfect for a blue/green screen or black velvet stretched with clips across the frame. Finally, a sliding track from Revolve and a ball-head camera mount let us position to get just the right shot. In the future it could even include a computerized motor for smooth tracking video. The final rig is pictured in Figure 2.7.

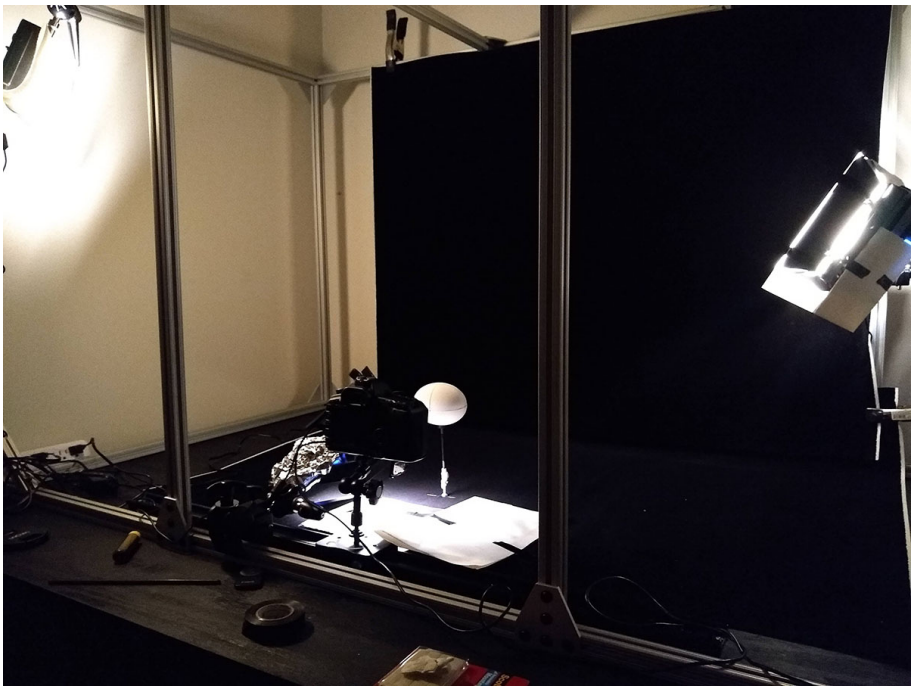


Figure 2.7: Photography rig in action.

All these things were an absolute joy to work on. The welding, the sawing, the constructing, even the painting of the table, felt like almost primal productivity. I have always felt in myself an innate desire to work with my hands: to build, to create, to indulge a visceral need to lay my hands on a result at the end of the day. This all could be said to be far outside the scope of DPA. Definitely unusual for a thesis, but I do consider it to be an integral part of the work of this year. To create a space that will endure. To give back to my cohort. To leave a mark on the program, even if it is just a small one.

Figure 2.8: Differences between prints from different printers.

2.3 Learning the 3D Printing Process

Coming into this project my knowledge of the 3D printing process was rudimentary at best. Any objects I had printed were printed for me by others. Fortunately, modern 3D printers have become quite user-friendly and easy to operate. I investigated the many forms of 3D printers on the market: FDM, SLS, SLA, and others. [11] While SLS and SLA would give a very precise print with fine detail and sturdy prints, they were both too expensive to be economically viable. Many other printer types proved difficult to source, and, again, quite expensive. I finally decided on the FDM (Fused Deposition Modeling) printers that I had easy access to and which would keep my overall project cost lower. I used both a LulzBot TAZ 6 and a LulzBot Mini printing simultaneously over a week. This did allow me to finish my printing faster, but there were drawbacks to printing on two different printers, the main being the quality of the prints. Different printers will print slightly differently from one another. Slight variations in the print heads will cause the filament to extrude at slightly different rates and at slightly different temperatures. Another drawback was that the printers were housed in different environments. Changes in ambient temperature and amount of air flow will affect the temperature of the print as well. These variations can create subtle differences between prints. [3] Looking closely at my prints, I could see slight differences, as shown in Figure 2.8, but they were not significant enough for me to abandon the two printer setup.

There are many types of filament available for FDM printers, each with its own set of advantages and drawbacks. [1] ABS, PLA, and PETG are the most common filaments for household printers such as the ones I had access to. After assessing my needs I decided on PLA (Polylactic Acid). PLA is easy to acquire on short notice, it is inexpensive, comes in a vast variety of colors, is low-odor, and can print quickly with a decent amount of detail. ABS and PETG, while they will create a quality print, are more suited to manufacturing parts that need to be durable and

survive harsh environments. Since my project did not need those benefits, I went with the PLA. Sorting through the various types and brands of PLA was a bit daunting. There are many companies manufacturing different types of filament at many different price points. At first I tried a light weight PLA called PolyLite by PolyMaker. While the PolyLite did produce acceptable prints, it proved difficult to maintain a constant temperature and thus a consistent feed through the print head. Without a consistent temperature a print will likely fail. [3] This was my experience. After the PolyLite I tried Verbatim's 1.75mm PLA filament. The Verbatim printed easier than the PolyLite with far fewer failed prints. The prints created were not the most detailed, but they were sufficient for this project.

Early on in the planning process for this project I concentrated on the idea of creating perfect prints. I considered sanding and finishing my models, or putting them through an acetone chamber to smooth out the inevitable ridges left behind during FDM printing. [7] These methods can be used to create extremely smooth prints that look very finished; almost as if they were sculpted in a different physical medium or cast by machine. I looked at my models and all the artifacts of the 3D print and decided I wanted to keep those details. That way my project would look 3D printed. The intention of this project was to showcase 3D printed sculptures. If they looked too finished it would lose that print quality, so I cleaned up any stray filament pieces and kept as much of the 3D print artifact as I could.

2.4 Storyboard and Shot List

Storyboarding an art piece like Pulse proved to be extremely difficult. Distilling an artistic and organic process down to a set of directions was a new experience for me. A narrative lends itself to easy storyboard creation. Shots are framed and characters identified. I knew I had to photograph my project, and I had to compose those photographs, but the idea of nailing down my project to something "set in stone" was unappealing and felt like a betrayal of artistic freedom. However, due to the daunting number of photographs I had to make, and the desire for the piece to have different compositions that were visually cohesive, I had to create rough storyboards and a detailed shot list.

For the sake of clarity and neatness, I chose to create my storyboards using my sculpted 3D models. This allowed me to see a more finished product than hand-drawn storyboards could afford. From this rough storyboard I was able to create an actual mock-up of the animation in Maya, timing

the angle changes and distention animations to the chosen music.

Once my storyboard was complete I was able to create my massive shot list. This was key since I had to know exactly which parts were in each shot. When dealing with over 1000 separate photos, knowing the exact content and number is invaluable. The shot list contained the frame number of the animation, the quadrant of the egg that was being distended, the type of distention (hand, face, fist, etc.), the model number within that distention series, the type of shot (wide, close-up, angle), notes on the musical cues, and a checkbox to ensure the photo was created. This exhaustive list made the photographing process much smoother.

(See Appendix C for storyboard and shot list examples.)

2.5 Musical Choice

I am not a musician, so personally creating a custom score for my animation was not going to happen. I had briefly investigated having a piece composed by a musician, but I found this to be cost-prohibitive. From there, I investigated the world of low-cost royalty-free music. There are quite a few sources of free-use music on the internet. It took quite a while to narrow my choices down to a few that were acceptable.

The first of my main criteria for the soundtrack was that it not be identifiable as a known piece of music. I did not want to detract from my visuals by pairing them to a piece of music someone may have preconceived notions about. For example, if someone was familiar with the music I chose, and had a bad association with that music, it would taint their opinion of my work. My second criteria was that it fit the piece. I wanted my work to have a synthetic and cosmic quality, but also have a beat reminiscent of a heartbeat. Something melodic, with a certain amount of eerie mystery to it. After a lengthy search I finally decided on one of the first pieces I had heard by the artist Bensound titled “Deep Blue”. It is not a lengthy composition, but at almost five minutes it provided me with enough music to cover the whole length of my project. “Deep Blue” also has several sections of near silence that can be used to split the music up or repeat sections as needed.

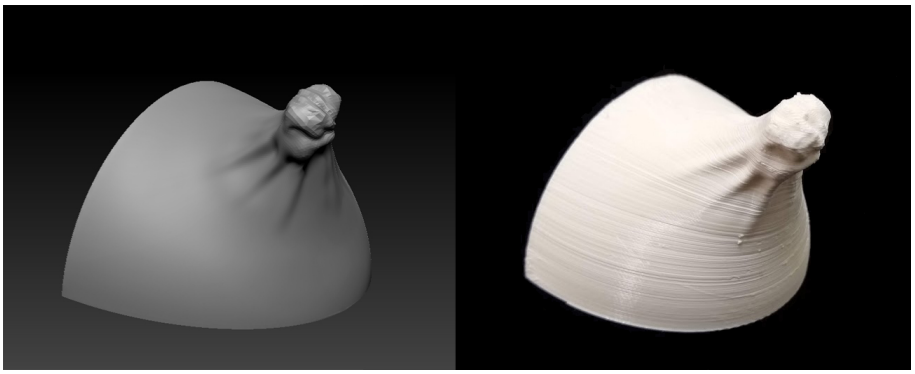


Figure 2.9: Comparison between fist model and print.

2.6 Choosing the Forms

When I began this project I had a vague idea of what type of forms I should use to distend the egg model. I knew I wanted them to be organic, as opposed to mechanical. I also knew I wanted the forms to be both human and creature: paws, claws, faces, spines, and unidentifiable organic deformations. When I started my first designs I had very detailed models in mind. I thought of subtly disturbing details such as human faces with creature teeth or human hands with deformed fingers. During my initial sculpting attempts, however, I quickly learned that small details would likely get lost in the translation between digital sculpt and 3D print. The differences can be seen in Figures 2.9 and 2.10. This necessitated a rethink of my models with a eye for the final 3D print fidelity. My forms became a bit simpler, but no less disturbing: a face with no teeth, the spine of an unknown creature, a very human hand.

My final decision was to create seven separate forms, shown in Figure 2.11. That would give me enough variation in my models, but still give me plenty of time to print all the pieces I would need. Each form has 24 distinct frames to its deformation animation. This represents a full 4-second cycle of distention at a rate of 12 frames per second. If an animation needed to be slowed frames could be repeated, or if a distention needed to be shorter frames could be cut.

In total I ended up with over 150 individual printed forms, shown sorted and organized into storage containers in Figure 2.12. When combined in different configurations, these prints created 1400 frames of animation.

Figure 2.10: Comparison between hand model and print.

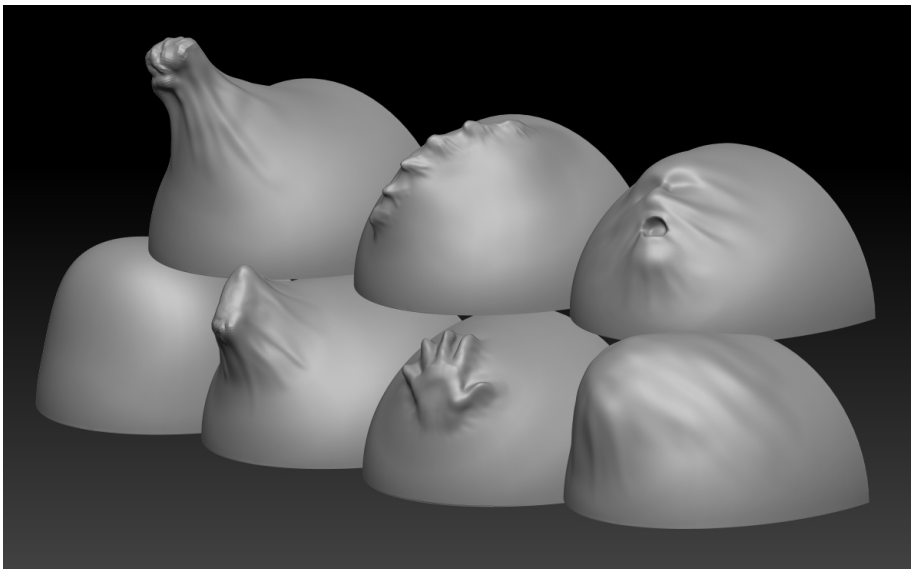


Figure 2.11: Chosen sculpted models

Figure 2.12: Printed models sorted and organized

Chapter 3

The Production Process

3.1 Sculpting the Forms

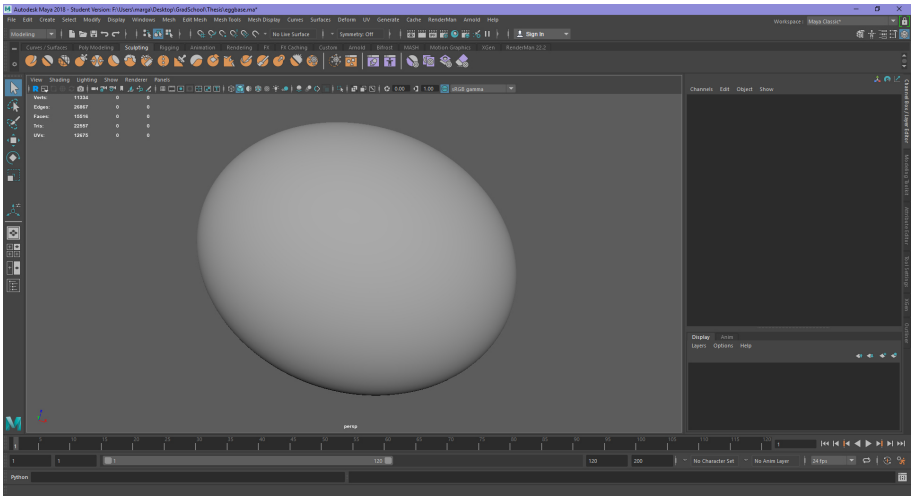


Figure 3.1: Initial egg shape in Maya.

First and foremost I had to create the basic egg primitive in Maya, as seen in Figure 3.1. It had to have an aesthetically pleasing proportion, but still be large enough to adequately show the 3D printed details.

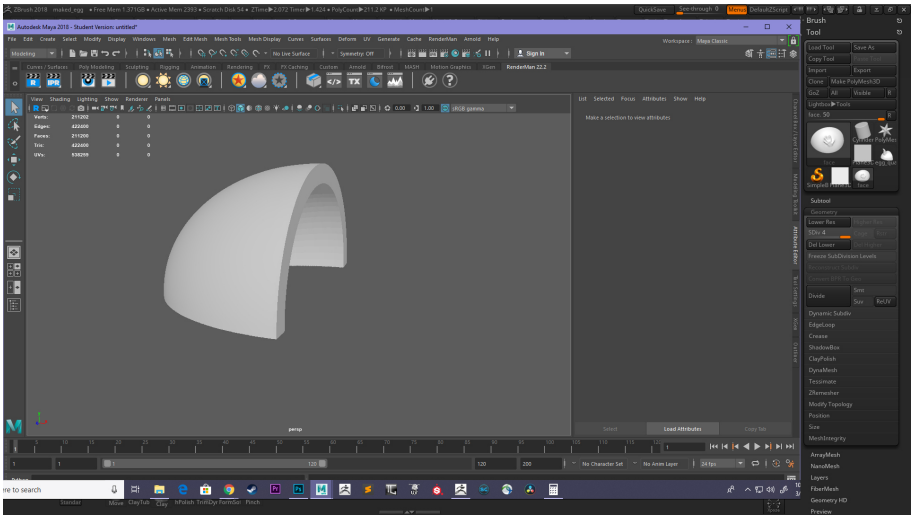


Figure 3.2: Quarter egg in Maya.

The egg was then sliced into quarters, shown in Figure 3.2, and extruded to create thickness of the wall. Each quarter was individually sculpted and printed to be interchangeable.

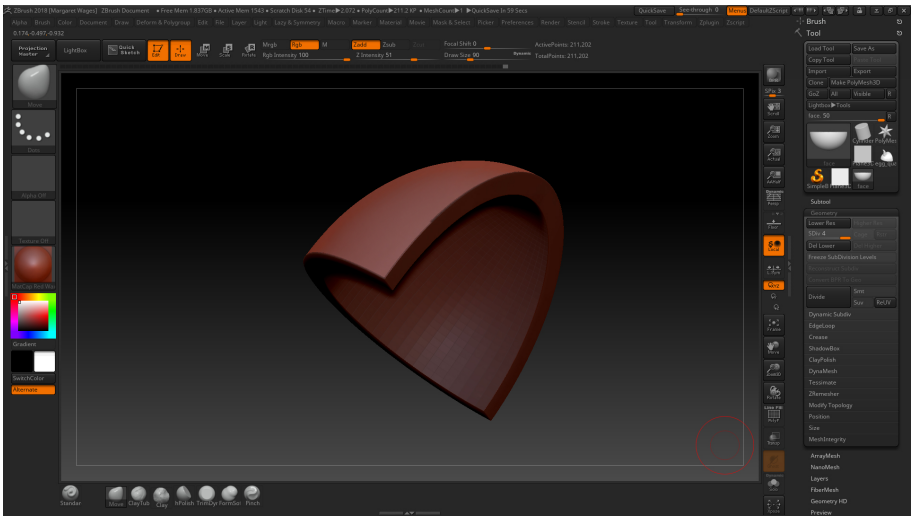


Figure 3.3: Quarter egg masked in Zbrush.

The egg quarter is brought into Zbrush. The edges and interior were masked off to prevent them from being affected by our sculpting, as seen in Figure 3.3, this ensured the pieces will fit together smoothly after printing.

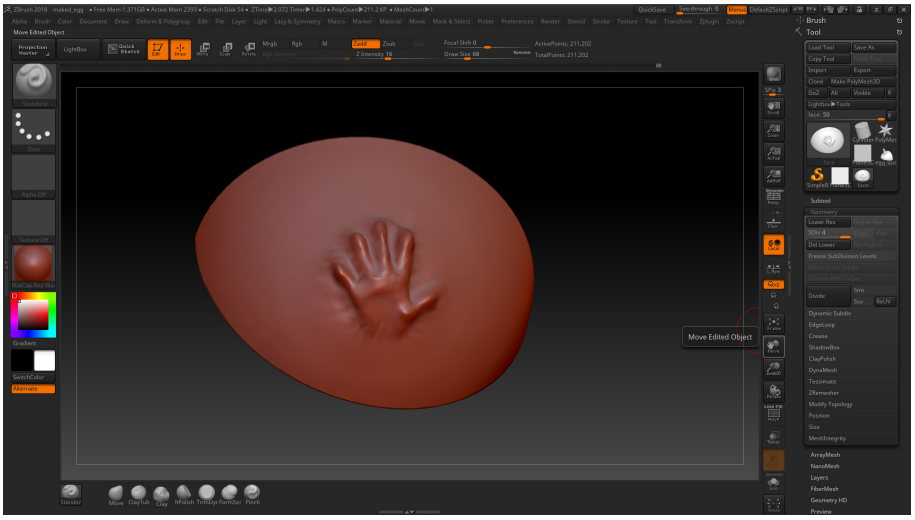


Figure 3.4: Sculpting in Zbrush.

Using a variety of Zbrush tools, the final deformation was sculpted — in the case of Figure 3.4, a hand pushing out from inside the egg.

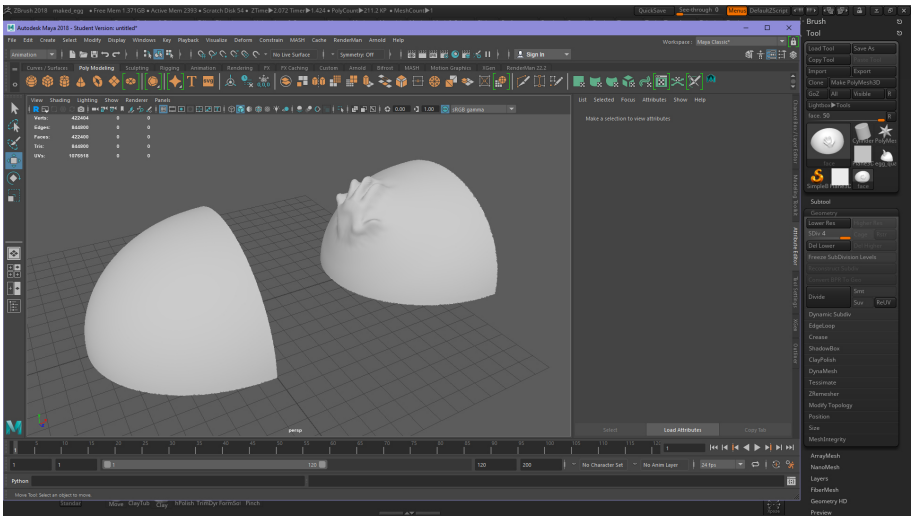


Figure 3.5: Original egg and sculpted egg back in Maya.

The newly sculpted quarter was brought back into Maya, along with the original unsculpted version. See Figure 3.5.

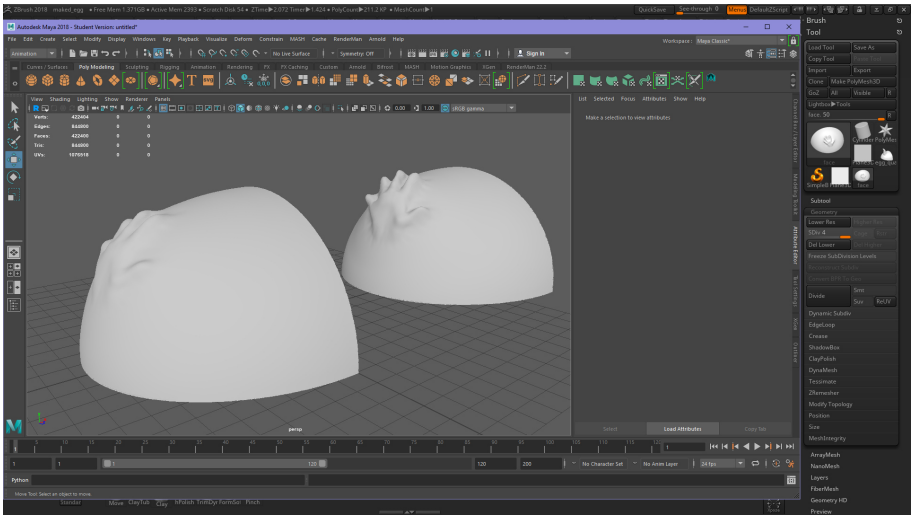


Figure 3.6: Blend shapes in Maya.

Using Maya's "blend shape" function, an animation was created between the unsculpted and sculpted quarters. The blend was then animated over 24 frames, or 2 seconds using our rate of 12 frames-per-second. Figure 3.6 shows the animation at the 1 second and 2 second marks.

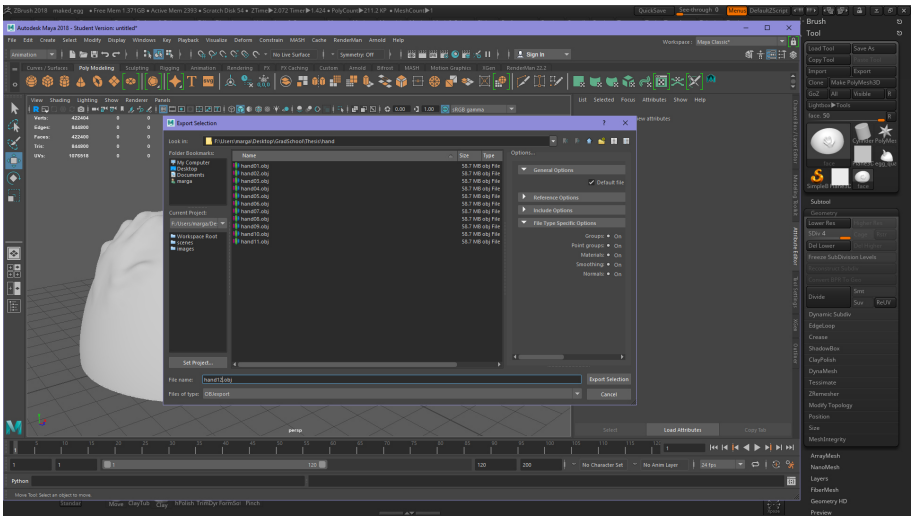


Figure 3.7: Saving out the individual frames.

Each frame of the animation was then exported as a separate .obj file, resulting in a series of 24 printable files. See Figure 3.7.

3.1.1 Original Idea

My final sculpting process was not my first idea. I originally had a different type of component system developed that would involve an egg with small interchangeable pieces that were more modular than the final design. Unfortunately, the parts proved too small and unwieldy for me to handle effectively.

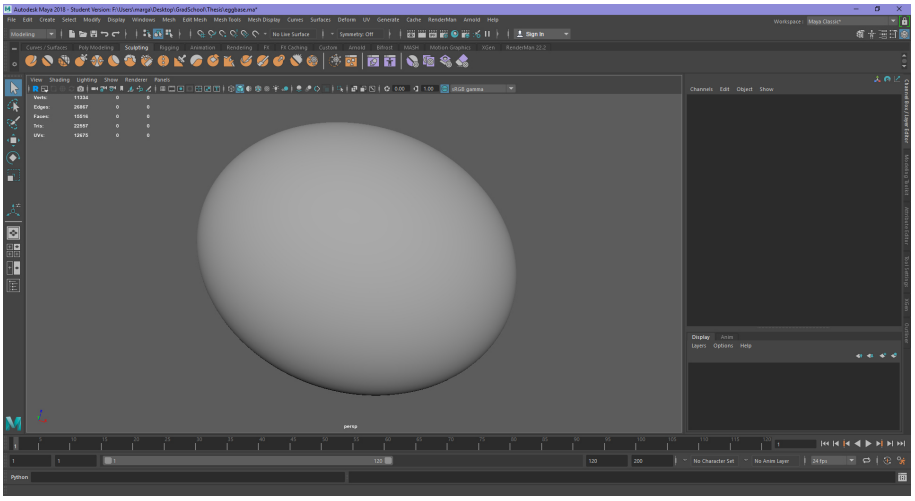


Figure 3.8: Original egg shape in Maya

Like the final design, and as shown in Figure 3.8, the original began with the simple egg shape created in Maya.

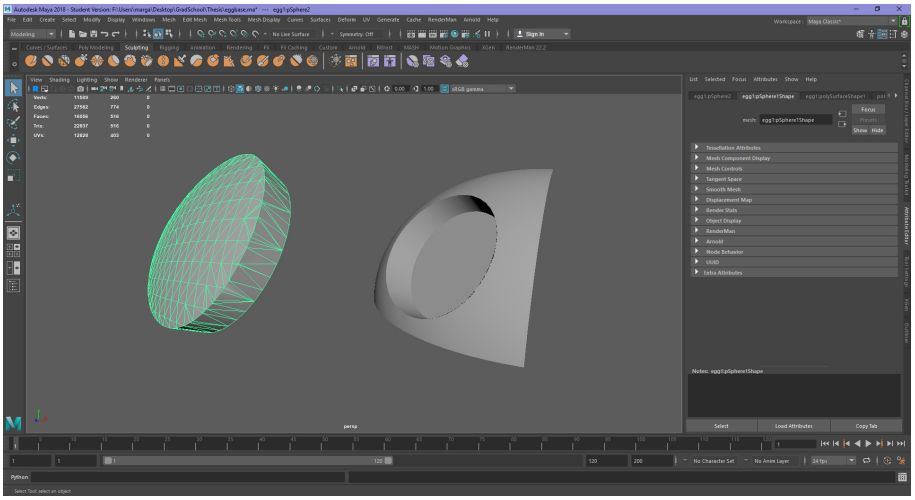


Figure 3.9: Extracted section of the egg.

The egg form was then divided into a single quarter, like the final as well. Instead of sculpting on an entire quarter, a small section in extracted via a boolean operation creating a platform to sculpt the deformation on. The extraction is shown in Figure 3.9.

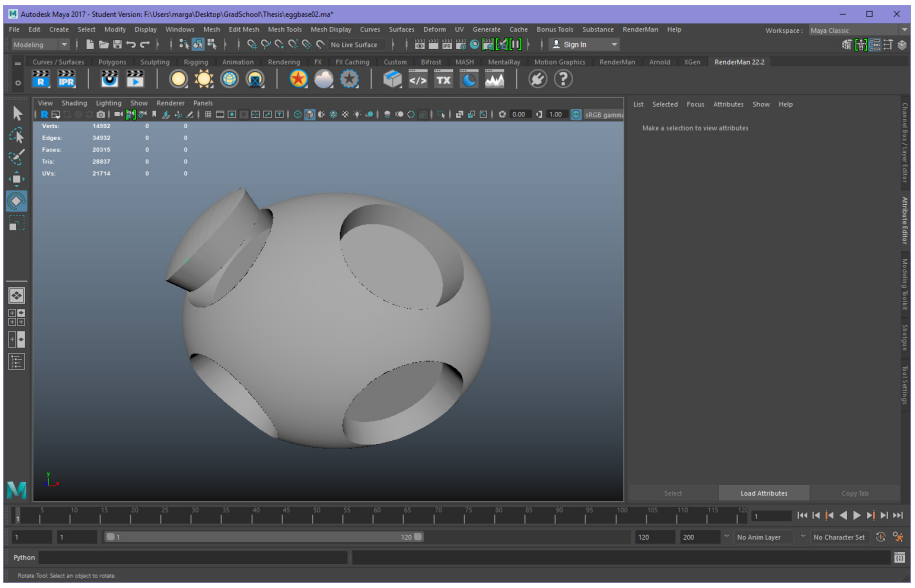


Figure 3.10: Multiple stages extracted.

The quarter is then replicated 3 times and rejoined to create a full egg with multiple locations

for the extracted platforms. The resulting full egg is shown in Figure 3.10.

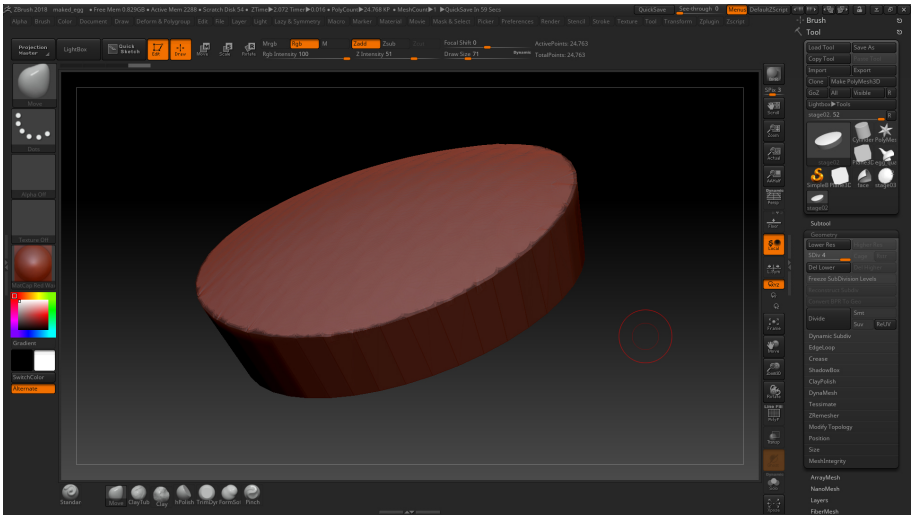


Figure 3.11: Stage prepared for sculpting in Zbrush.

The platform was then brought into Zbrush, as seen in Figure 3.11, where the underside and sides were masked off to prevent them from being deformed by the sculpt. This ensured that the platforms fit back into the original egg form cleanly.

Figure 3.12: Concept print.

A test-print, shown in Figure 3.12, proved that the interchangeable pieces would be too difficult to effectively be interchanged while leaving the main body of the egg unmoved. Thus, the design had to be reworked with larger interchangeable objects.

3.1.2 The Printing Process

Once I made the final choices for physical printers and materials, the printing became a relatively easy exercise in patience. Printing takes time. I did find a few ways to speed up my process.

First, I thinned out the walls of the models. When I first sculpted the models the thickness of the shell was approximately 1/4" at its thinnest. After my first test print of a few of those models, I realized I did not need to have that much wall thickness. These did not have to be structural models, they just had to hold together through photography. I reworked the shell down to 1/16" and found that the egg quarters held their shape just fine, and cut my printing time down significantly.

Second, I got rid of any printing supports. When a 3D model is printed the slicing application will sometimes add printed support material under certain parts of the model to keep it from

deforming during the printing process. For example, a figure with a raised arm will have print supports under the arm so it will not sag during printing, and those supports are removed at the end. While my shells did have a large open area under them, the angle of overhang and weight was not substantial enough to necessitate the application recommended supports.

Third, I laid out the models in a manner to best utilize the printer bed. The less a print head has to move between models, the faster the print.

Fourth, I resized my models. My original idea was to use a 6" wide egg, but shrinking the models down to approximately 4" wide cut back on time and material. With those streamlining processes in place I was able to print at a much greater rate than I had initially expected.

From there the assembly-line process of printing began.

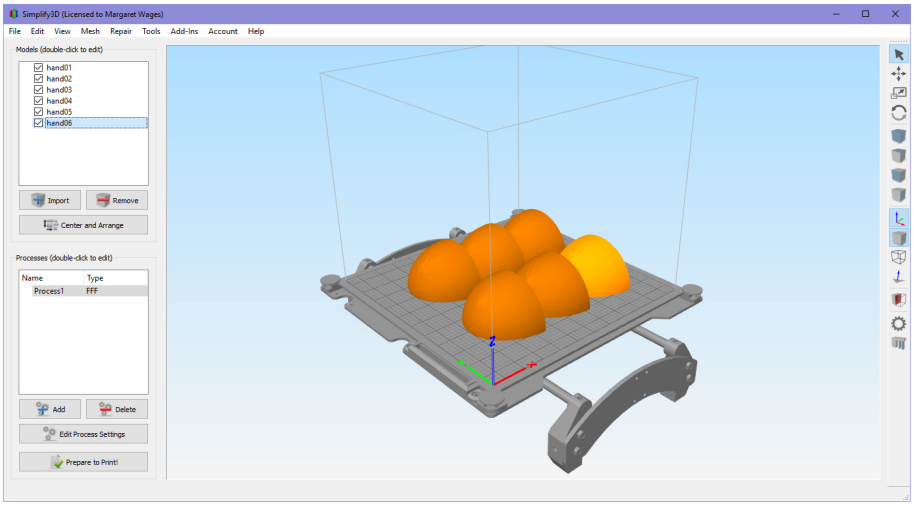


Figure 3.13: The egg quarters prepared for printing in Simplify3D.

Once the models had been exported as OBJ files, they were imported into the slicing application Simplify3D. This application prepares the files for the printer using either default or custom settings. It was here that I was able to get rid of the support material, and scale my models down to the 4" size. Once laid out in an optimal order for printing, as shown in Figure 3.13, the models were ready to send to the printer.

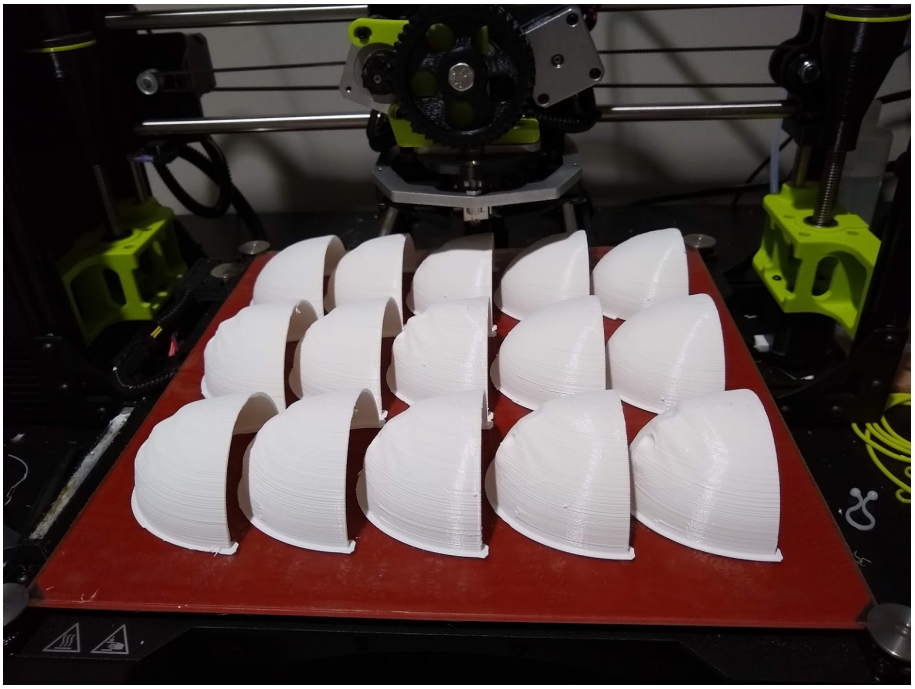


Figure 3.14: Egg quarters finished printing on the LulzBot TAZ6.

My larger printer, the LulzBot TAZ6 shown in Figure 3.14, was able to print up to 15 models at a time. It took about 16 hours to print the 15 models at my chosen medium resolution.

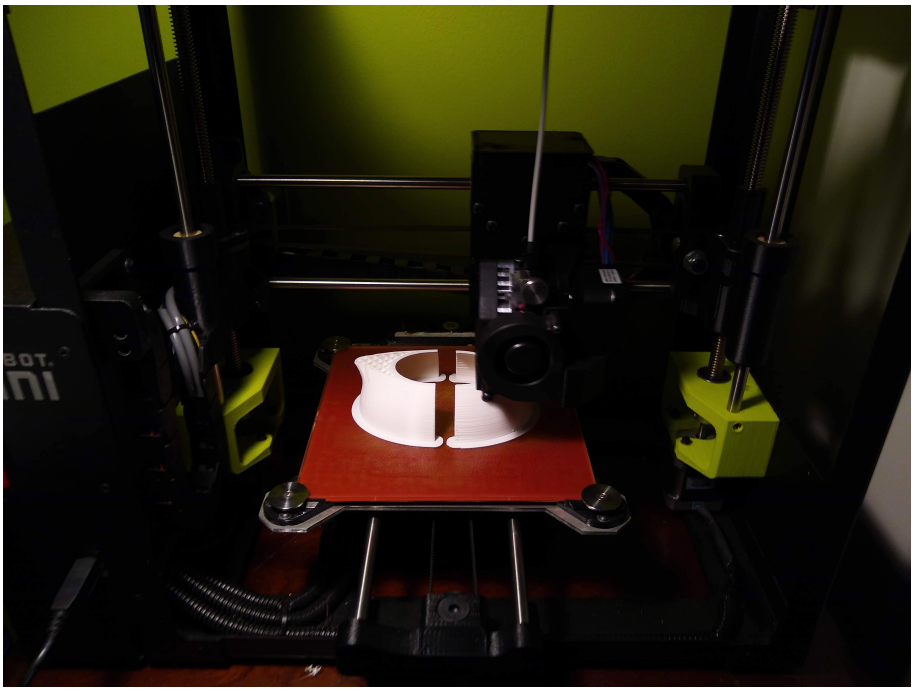


Figure 3.15: LulzBot Mini

The smaller printer, the LulzBot Mini, was only able to print 2 models at a time, as seen in Figure 3.15. It took around an hour and a half to complete the 2 models. Although this was less efficient than the larger printer, it did provide valuable additional printing bandwidth.

3.2 Photographing Frames

The photography process for stop-motion animation is an exercise in patience and precision. Every frame is a separate photograph. While the slightest difference in camera or model placement might not be noticeable frame to frame. If one frame is out of alignment, and the next frame is based upon the positioning of the first frame, a small movement might compound throughout the scene, ending in a larger movement noticeable in the final production. For example, if I accidentally bump the model base while exchanging a part between frames and do not correct that movement, the next part I place will be based upon that accidentally bumped model. If we are moving across the stage to a specific place now we have moved too quickly and will arrive at our destination a few frames too early.

This care and precision just takes time; there is no easy way to do it. I did set up my model with a sturdy frame to lessen any accidental movement, and luckily I encountered very few frames that were off their expected mark. The magnetic base proved to be very sturdy, and the magnetic and clay substructure of the model kept its place throughout the production.

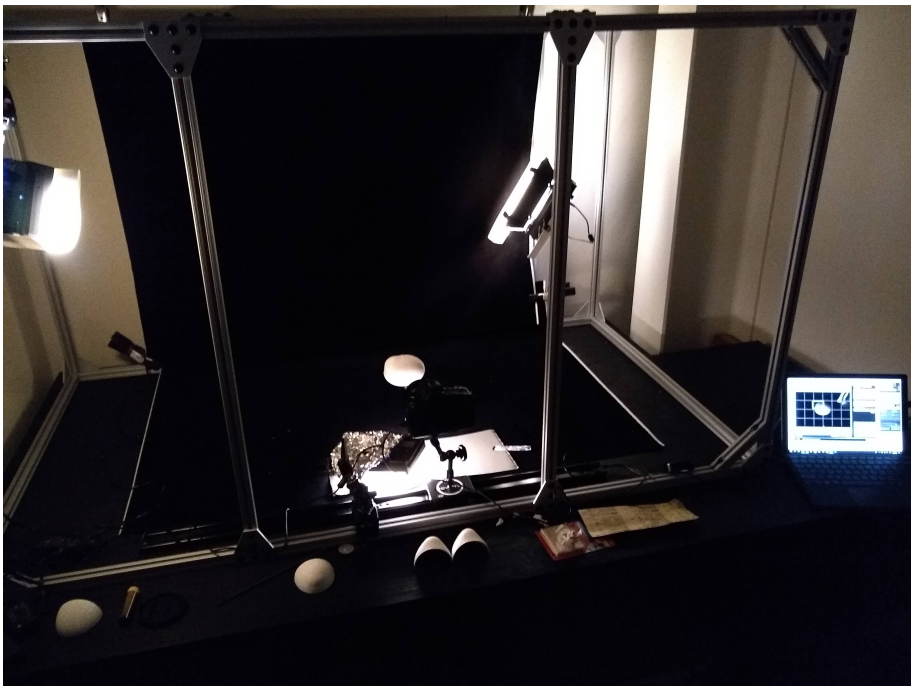


Figure 3.16: Photographing frames

It is not only easy to make small accidental changes in the position of the model, but also in the position of the camera. Even the act of pressing the shutter button can cause the camera to move. While I did have a very sturdy camera mount, I did not want to rely solely upon that. The Canon EOS series has the ability to connect to a computer via USB, shown on the righthand side of Figure 3.16, and be controlled by the EOS Utility application on the computer. The EOS Utility allows the user to control the various features of the camera (f-stop, ISO, white balance) without touching the body of the camera. It also has a virtual shutter button to make the photograph without touching the camera. This proved an invaluable feature when making multiple photos without moving the camera body.

Chapter 4

The Post-Production Process

4.1 Photo Manipulation

Once I had finished the photography, I had to ensure the photographs would fit together into a cohesive project. Since the models were made up of four distinct quarters, and I wanted the egg to look like a solid object, I had to heal the seams between the quarter models. This was achieved using the clone stamp in Photoshop, as seen in Figure 4.1. A few of the photos also had to be rotated so the eggs would line up between frames of the animation. The photos required surprisingly little modification. This was due mostly to the accuracy of the rig that held the egg models and the camera mount that kept the camera in an exact position.

I used a black velvet backdrop to my photos so the matting process was fairly straightforward. The lighting rig and model stand that were visible in the photos were removed using a

Figure 4.1: Original photo vs. Healed and masked photo.

"garbage matte", a hand-painted overlay that specifies areas of a photo that should not appear in the final production. The black velvet in the rest of the background photographed as solid black so nothing had to be done to the area adjacent to the egg, it was left solid black.

4.2 Grading and Compositing

Stop-motion animations are, unless they are produced by large studios, shot at 12 to 15 frames-per-second. Large studios are able to dedicate significant monetary and personnel resources to a project and can afford to shoot at 24 frames-per-second, but an individual or small operation would be hard-pressed to produce and composite that many separate photographs and still create a project of any length. This is one of the main reasons traditional stop-motion animation productions have a signature "jerky" look to them. For the human eye to interpret a series of photos as simulating movement, that series must be show at 12 frames-per-second or higher. [20] The higher the frame rate, the smoother the eye interprets the movement. The world of digital animation uses a frame rate similar to that used in traditional film-making, 24 to 30 frames-per-second or higher. Although this project had a large digital component, I wanted it to feel more like a traditional stop-motion animation; therefore I went with a 12 frames-per-second rate.

Modern compositing and editing software is geared towards editing footage at 24 frames-per-second and higher, but will often allow a custom frame rate. I chose to work with Adobe Premiere and After Effects because Adobe makes it easier to set up the frame rate and to keep it more consistent across the production than other software does. I was able to composite my project together and see it laid out at 12 frames-per-second instead of having to duplicate frames to play it back at 24 frames-per-second. This made frame-by-frame editing much easier.

For color grading and atmospheric effects I used Adobe After Effects. Using After Effects' Lumetri color grading utility, I was able to create the yellow-green color palette I desired. Using their Hue Saturation Curves, I was able to leave the black background untouched while creating the green tinge on the model. I also made use of After Effect's particle systems to create grunge and noise in my production. By creating a few particles and running them through a turbulence field I was able to create the effect of the egg being suspended in a viscous fluid.

Chapter 5

Conclusions and Discussion

5.1 Creating a Successful Multimedia Art Piece

There is no road map for creating a stop-motion animation production. Not many authors have set down any kind of step-by-step guide. Those who have tend to stick to the realm of the hobbyists working with their mobile phones and children's toys on a weekend. This is why the thought of creating a stop-motion production excited me. It is not something that is done every day — especially with an artistic final product in mind. I wanted to work on something that was a departure from the traditional digital production projects. I wanted a project that would require not only research, but extensive trial and error experimentation. Because I had no published guide I felt I could strike out on my own to find the best methods for my own personal work. Having a set of instructions will, of course, make a project easier, but I had to ask myself if I would obtain the same sense of personal satisfaction if I completed a project that was outlined for me by others. Looking back on my work and feeling the sense of pride and accomplishment I feel on its completion, I can honestly say that I chose the correct path. I have not only completed an impressive project, but I have added something new to the world — an art piece that has, although inspired by the works of others, never existed in this type of format.

When I look at the finished production, shown in Figure 5.1 I find myself able to feel the sense of unease and foreboding I intended from the start. The way the 3D printing artifacts on the surface of the egg form jitter and shake as if crawling and alive is exactly as I imagined. The egg deforms relatively smoothly, but not so smoothly that it could be mistaken for anything but

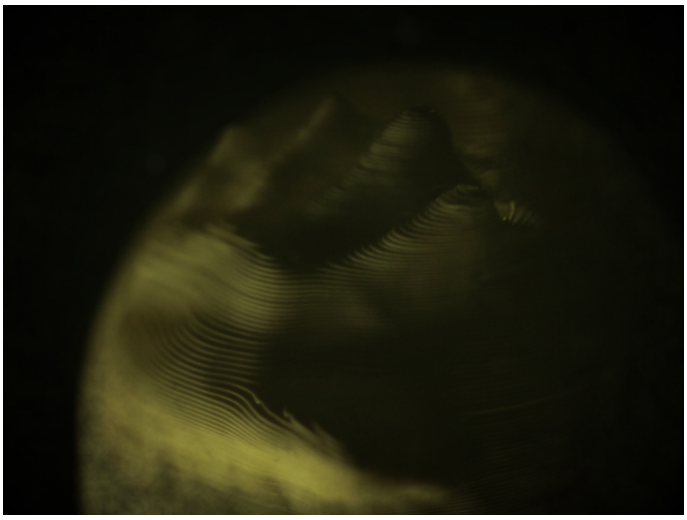


Figure 5.1: A still frame from the completed *Pulse* production

a stop-motion animation. The physical details of the printed models shine through the necessary digital manipulation. The tangible has successfully crossed through the intangible and retained its inherent nature. Watching the production I can see that I am viewing photographs of real world objects, and if they are real objects then perhaps the creatures within are just as real. Perhaps someone somewhere has released digital horrors out into the physical realm. I would say that the gap between the tangible and the intangible is truly bridged by this work. The piece looks as it is supposed to look, and works as I had intended, and I therefore consider it a success.

5.2 Extensibility and Program Growth

One thing I have kept in mind throughout this project: what is the next step? Where do we go from here? Not for myself necessarily, but for the future of similar projects. As I have been building the photography rig and been developing the print production process, I have kept in mind that I am most likely not the last student at Clemson Charleston to undertake such a project.

This leads me to the question: do I think this could work as a multi-student production studio project? The answer is yes, but with a few caveats. I wholeheartedly believe a 3D printed stop-motion animation project would be an ideal production studio project for a second- or third-year Master's degree student. Printed stop-motion incorporates several elements from across multiple disciplines and would allow students to experience several portions of the production pipeline that

differ from the traditional animation projects they may be used to working on.

First, this deals with not only 3D modeling, but with 3D modeling for printing. This requires a different set of fundamental rules for what can and cannot exist. The process of printing creates a certain amount of physical limitation as to what can be achieved. For example, a character in flight cannot simply be key-framed across the stage. Wing models must be adjusted or replaced. The character body must be physically moved from point A to point B by a rigger.

Second, there is a need for knowledge of physical lighting and camerawork. All animated productions do include elements of these, but there is a certain increase in difficulty when dealing with real-world cameras and lights. Many students come in with little to no knowledge of such things, so a stop-motion project would lend itself to learning the practical side of production.

Third, this gives the students the ability to manage a production that exists both in the physical world and the virtual. Asset management goes from being easily implemented using a specialized tool to hands-on physical asset management. Once a printed asset exists, it must be carefully cataloged and handled. Chains of custody must be established so pieces do not go lost or misplaced.

Depending on the student group, these differences may cause undue burden. However, if a group wants to create a real-life stop-motion product, it is definitely workable. It would just require a few changes in thinking from the traditional production project we've become used to.

What about the practical side? I believe, with the work I have put in, we now have sufficient resources to begin a full multi-member 3D printed production at Clemson Charleston.

5.3 The Environmental Impact of 3D Printing

3D printing is an amazing new technology. It is allowing for incredible advancements not only in the artistic world, but across all disciplines, from medical and engineering to the humanities. Unfortunately, 3D printing does have one very large negative side effect: plastic waste. While there are printers that use metal or glass to create structures, more easily accessible thermoplastic extrusion printers use polymers that are not easily broken down or biodegradable. That is not to say that nothing can be done to make the process of 3D printing greener. While polymers do present a recycling hurdle, some plastics are more easily broken down than others. [6] [15] I chose to use PLA for my project because it can be collected and recycled by specialty firms.

While this does mitigate some of the concern for the environmental impact of 3D printing in general, it still leaves open the debate on whether a piece of 3D printed art is necessary to begin with. I will admit that the environmental impact of my own work was not one of the top concerns I had when I began. I did, toward the end, begin to take into consideration the amount of plastic waste I was producing and attempted to curtail it as much as possible by lining up prints to use the least amount of filament, and collecting as many scraps as possible for future recycling. That said, a 3D printed animation is not a project to be undertaken if one is to lead a life of minimal environmental impact. There are many pieces to be printed, and a high likelihood of misprints that must be discarded. I do not think these concerns should completely dissuade anyone from a future 3D printed project, but I do believe they should be at least taken into account before choosing to proceed.

Appendices

Appendix A Technical Specification Sheet

Item	Product	Reasoning
Printers	Lulzbot TAZ 6, Flexydually head Lulzbot Mini, Aerostruder head	First acquired by school, second personal machine
Filament	Verbatim PLA, 3mm, white	Good combination of value, ease of print, and finish
Component connection	Standard magnets	Easy to attach and detach interchangeable segment
Camera	Canon EOS Mark II / ISO 2000	Already owned, high quality image capture
Lens	Venus Optics Laowa 15mm f/4 Macro	Ease of use and ability to capture close with good fov
Lighting	3 x Bescor FP-312T	Adjustable temperature and intensity.
Lighting mount	Impact Super Clamp	Easy to clamp on to aluminum frame.
Stage Frame	1" extruded aluminum, 5.25' x 3' x 3'	Easy to assemble/disassemble. Extensible.
Backdrop	Blue cotton backed with light blocking flocked velvet	Allow for blue screen.
Stage	24" x 36" Steel plate on top of custom welded table	Allows a stable surface to stand on. Steel plate allows for attachment of pieces by magnet for precise placement.
Software	Maya 2018, Zbrush 2018, Simplify3D, Cura 3.6.3, Canon EOS Utility, Adobe Photoshop CC, Adobe Premiere Pro, Adobe After Effects	

Appendix B Concept Art

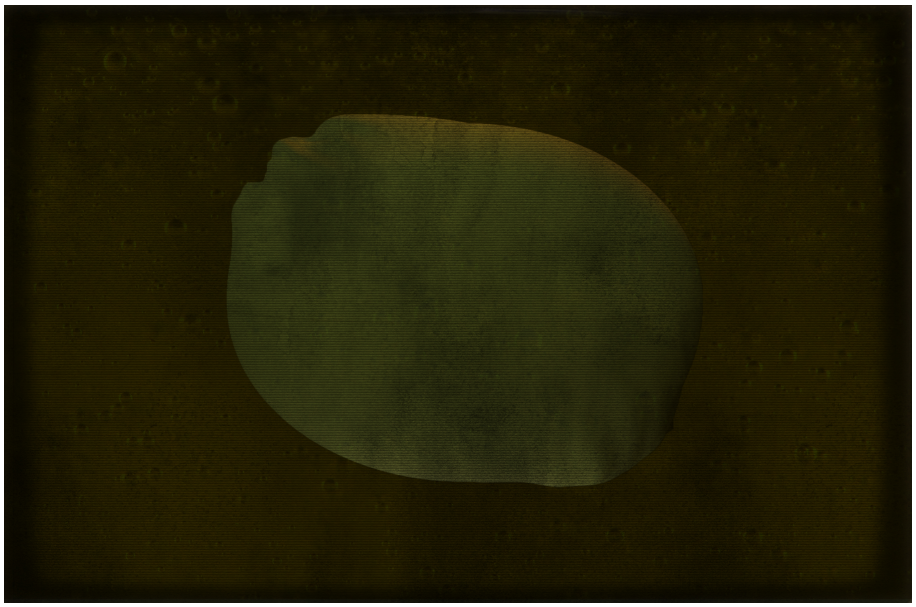


Figure 2: Original concept art. Very dark. Egg suspended in oil. Grunge and CRT grain applied.

Appendix C Storyboards and Shot List

C.1 Sample Storyboards

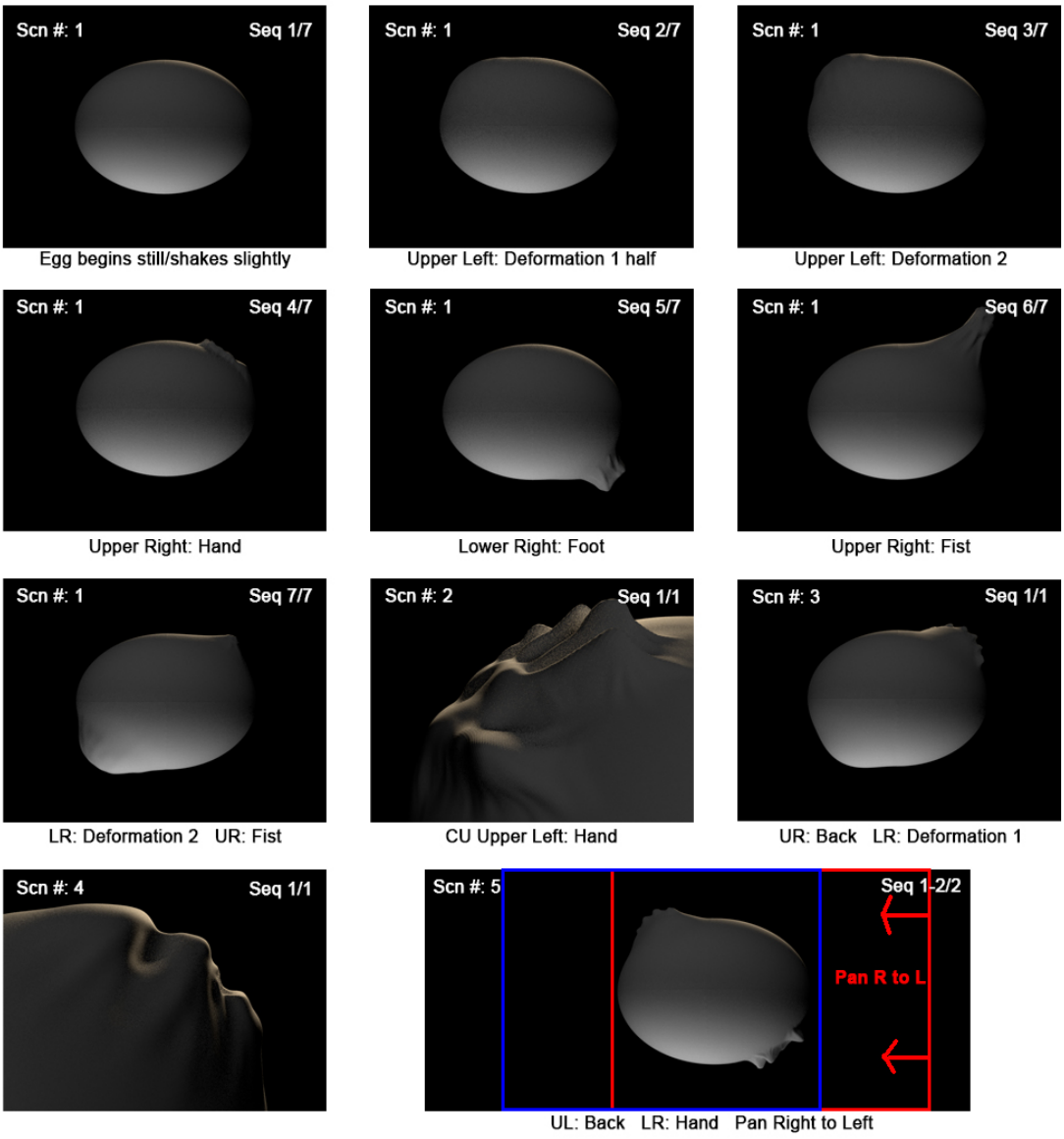
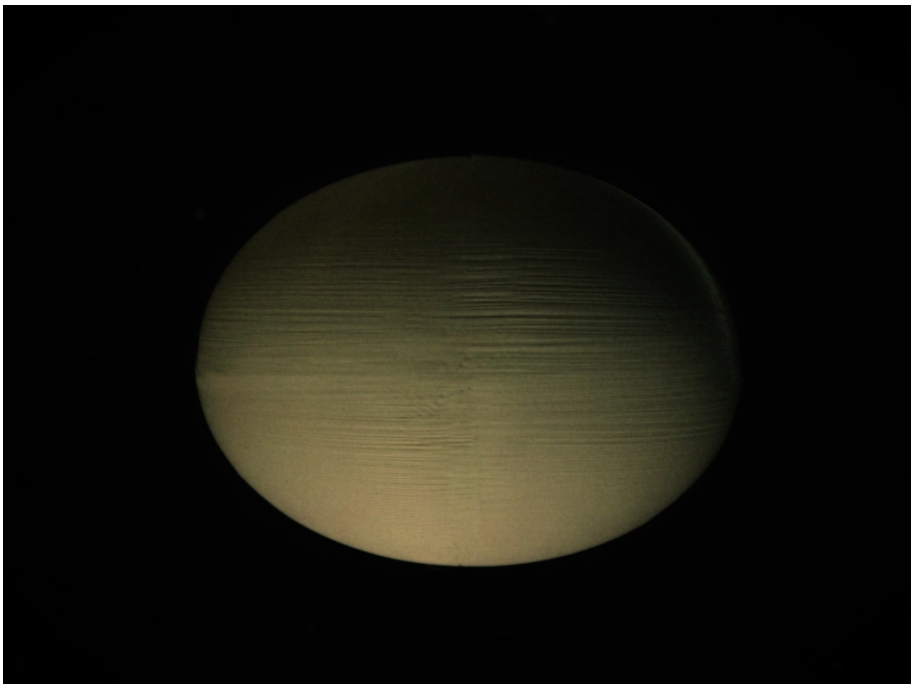


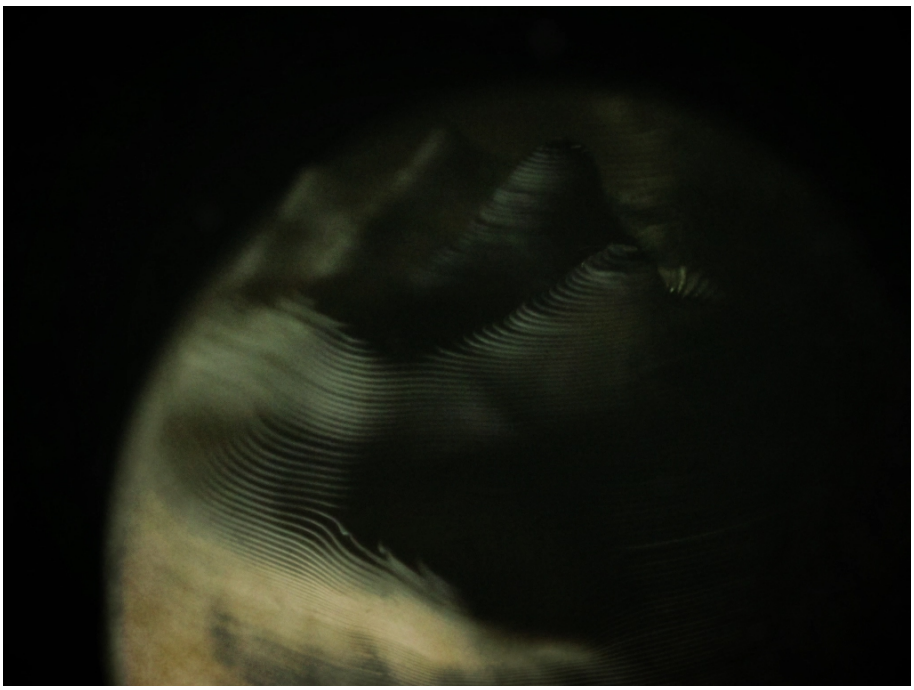
Figure 3: Sample Storyboard

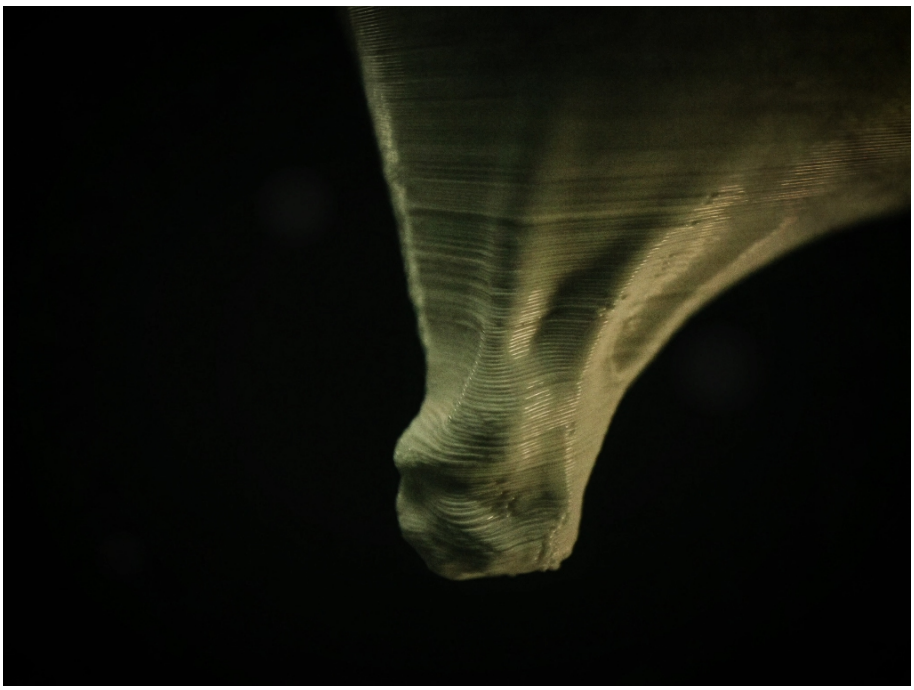
C.2 Sample Shot List

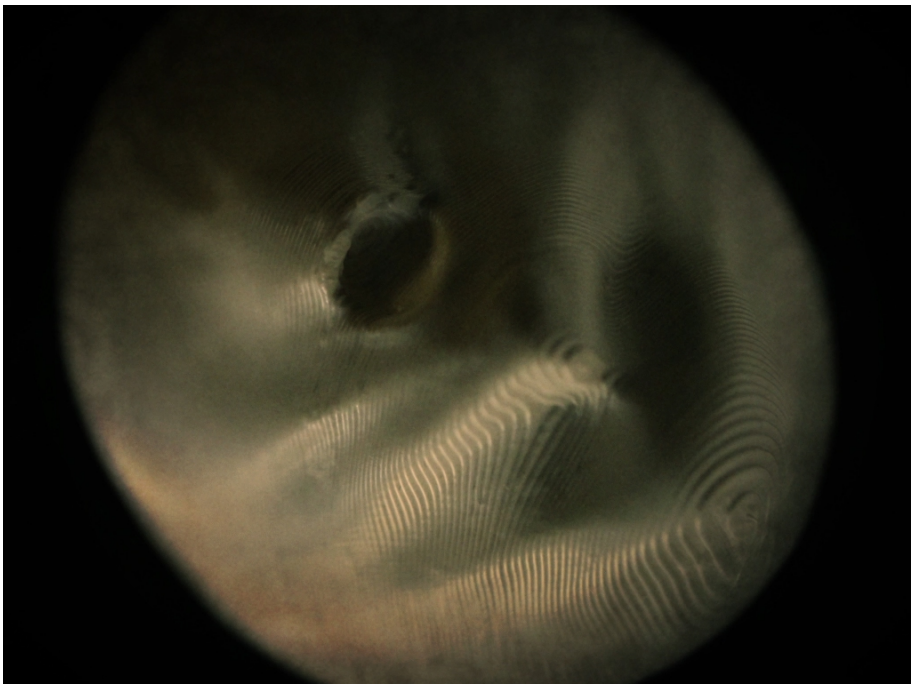
	Upper Left		Upper Right		Lower Right		Lower Left				
Frm.#	Model	Model#	Model	Model#	Model	Model#	Model	Model#	Shot	Photo	Sec.
508	Back	16	Base	Base	Base	Base	Hand	20	WS	X	43
509	Back	17	Base	Base	Base	Base	Hand	21	WS	X	43
510	Back	18	Base	Base	Base	Base	Hand	22	WS	X	43
511	Back	19	Base	Base	Base	Base	Hand	23	WS	X	43
512	Back	20	Base	Base	Base	Base	Hand	24	CU	X	43
513	Back	21	Base	Base	Base	Base	Hand	24	CU	X	43
514	Back	22	Base	Base	Base	Base	Hand	24	CU	X	44
515	Back	23	Base	Base	Base	Base	Hand	24	CU	X	44
516	Back	24	Base	Base	Base	Base	Hand	24	CU	X	44
517	Back	24	Base	Base	Base	Base	Hand	24	CU	X	44
518	Back	24	Base	Base	Base	Base	Hand	24	CU	X	44
519	Back	24	Base	Base	Base	Base	Hand	23	CU	X	44
520	Back	24	Base	Base	Base	Base	Hand	22	CU	X	44
521	Back	23	Base	Base	Base	Base	Hand	21	CU		44
522	Back	22	Base	Base	Base	Base	Hand	20	CU		44
523	Back	21	Base	Base	Base	Base	Hand	19	CU		44
524	Back	20	Dist. 2	1	Base	Base	Hand	18	CU		44
525	Back	19	Dist. 2	2	Base	Base	Hand	17	CU		44
525	Back	18	Dist. 2	3	Base	Base	Hand	16	CU		44
525	Back	17	Dist. 2	4	Base	Base	Hand	15	CU		45
525	Back	16	Dist. 2	5	Base	Base	Hand	14	CU		45

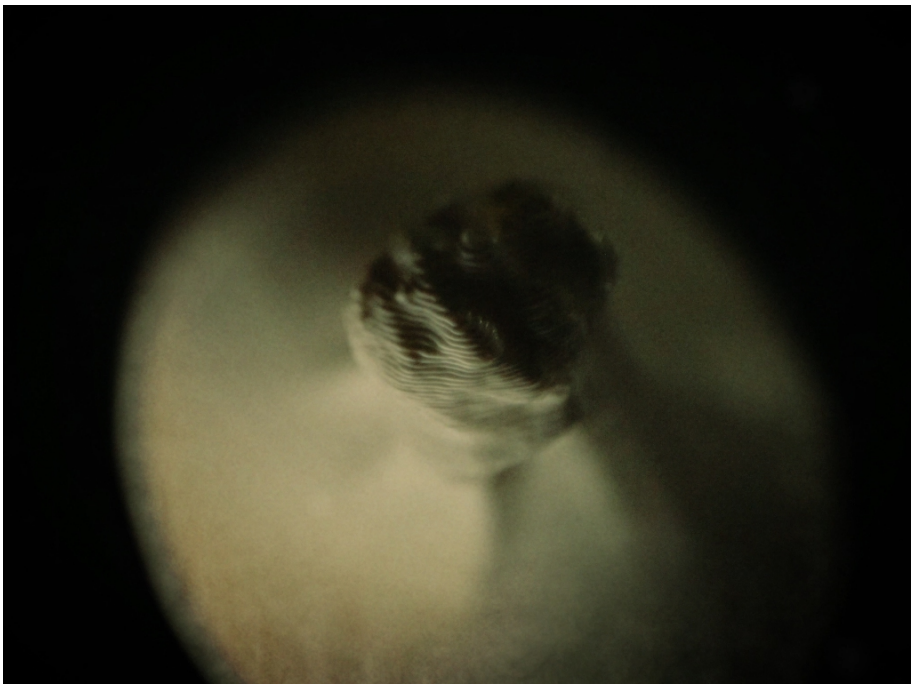
Appendix D Final Production Stills

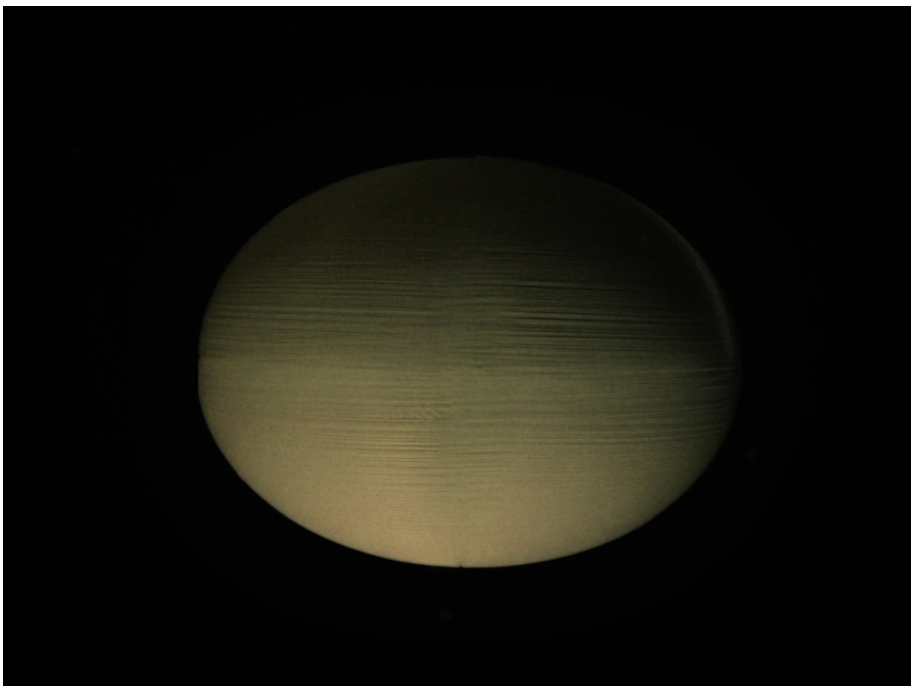












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